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13. ABSTRACT (Maximum 200 words)

The research funded by this grant is for the investigation of computerized ionospheric tomography as a method for characterization of the ionosphere. This research looks at specific degradation factors and develops compensation techniques and new CIT algorithms that mitigate or minimize their effects. Research has progressed in three categories: design and analysis of a time-varying algorithm to remove the resolution degradation effects caused by ionospheric motion, investigation of localized algorithms to compensate for the angular restrictions of the CIT system and the development of a CIT algorithm and system testing suite. Of note is the research into the effects of ionospheric motion on CIT reconstructions. It was shown that even simple linear motion can result in significant errors in peak height estimates using CIT algorithms which do not account for the motion.

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Research has progressed in three categories: design and analysis of a time-varying algorithm to remove the resolution degradation effects caused by ionospheric motion, investigation of localization algorithms to compensate for the angular restrictions of the CIT system, and the development of a CIT algorithm development and testing suite.

The first area of research is in the development and analysis of a time-varying algorithm. Successful development of this algorithm would enable more accurate CIT characterization of the ionosphere and imaging of dynamic ionospheric distributions. This is critical because our research has demonstrated that even simple linear ionospheric motion can cause a significant error in the estimate of peak heights in CIT algorithms which do not consider motion effects.

An initial algorithm (TVCIT) has been developed based upon previous research on static algorithms. This algorithm uses a three-dimensional system model where time is treated as an independent variable. It combines the basis function approach found in the Residual Correction Method (RCM), the use of physical constraints found in the Smoothness and Conjugate Gradient Approach (SCG), and flexible incorporation of additional sources of data such as GPS and ionosondes. Simulated results have shown that with sufficient combinations of data, accurate time varying CIT reconstructions can be achieved. The algorithm has been used to examine the effectiveness of various data sources and combinations of data sources. Results were presented at the recent CIT conference in Austin, TX. A significant limitation of the first implementation of this algorithm, however, is the cumbersome computation. As a result, the resolution achieved is currently limited by computational considerations. Current and future research is focused upon a computationally efficient implementation that would allow further study into the reconstruction of time-varying ionospheric features. Research is also analyzing the resolving capability of such an algorithm and its sensitivity to various types of movement.

The second area is in the design of algorithms which enable localized enhancement using a priori information. This work is a continuation of several previous efforts looking into localized enhancement during the reconstruction process, including the space-frequency algorithm. Current research is aimed at developing an algorithm for three-dimensional static CIT using volumetric constraints. These constraints are used in both the data and image domains and are based upon characteristics in the measured data and their similarities to a priori information. One of the goals is to develop an algorithm capable of selective inclusion of a priori data. This would allow image enhancement without overly stringent restrictions on the final reconstruction, which is a problem with some current a priori based algorithms. Preliminary results from a two-dimensional version of the algorithm (VSIRT) have been very promising. High quality reconstructions were achieved with a variety of a priori sets having different degrees of correlation to the original image. Current and future research focuses on enhancing this algorithm, extending it to three-dimensions and adding capabilities for incorporating additional data types. This set of algorithms is especially promising for applications such as ROTHR which have localized regions of interest.

The third area of research is in the development of a CIT algorithm test suite in conjunction with Dr. Gary Bust at the Applied Research Labs in Austin, TX. The goal is to combine our research in defining ionospheric features of interest, characterizing fundamental ionospheric image characteristics, and developing analysis techniques for evaluation of the quality of reconstructions, with his work in the development of a modular CIT system. This test suite would allow researchers to use a common set of test images with variable parameters for algorithm evaluation, a common set of data simulation algorithms for testing the effectiveness

of additional sources of data, and a common set of image evaluation algorithms for judging algorithm effectiveness. Furthermore, a variety of existing algorithms will be incorporated into the test suite to allow testing of those algorithms and comparisons between various CIT approaches in a controlled setting. We have determined a platform (IDL/Explorer) which will enable us to combine our image and data generation algorithms, reconstruction algorithms and image evaluation algorithms with his set of algorithms. Current and future work is focused on porting our algorithms (RCM, VSIRT, TVCIT) and techniques to this platform, development of image evaluation techniques, characterizing fundamental image charcteristics and collaborating with Dr. Bust on the design of this test suite.

Attached to this report are the following papers, theses and presentation abstracts which provide technical details on the research performed. Several additional journal papers reporting on this research are in preparation and are expected to be submitted to Radio Science and the Journal of Imaging Systems in the near future.

H. Na and E. Sutton, "Time Varying CIT", Proc. of CIT Conference, (in press).

C. Biswas and H. Na, "A CIT Reconstruction Algorithm Using Volumetric Constraints", Proc. of CIT Conference, (in press).

C. Biswas and H. Na, "Limited Angle Tomography Using Volumetric Constraints", Proc. of IEEE Conf. Image Processing, (submitted).

C. Biswas and H. Na, "A Volumetric Guide to ART based CIT Image Reconstruction", Abstracts of 1997 URSI Radio Science Meeting, (in press).

H. Na and C. Biswas, "Localized Space-Frequency Algorithm for Computerized Ionospheric Tomography", Radio Science, vol. 31, no. 6, pp. 1555–1566, 1996.

E. Sutton, "Tomographic Reconstruction of the Time-Varying Ionosphere", PhD Thesis, University of Iowa, 1996.

L. Schueller, "Sensitivity Analysis of Ionospheric Tomography Algorithms to System Configuration", MS Thesis, University of Iowa, 1996.